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UNITED NATIONS ENVIRONMENT PROGRAMME

ECONOMIC ASPECTS OF THE EFFECTS OF POLLUTION ON THE MARINE AND ANADROMOUS FISHERIES OF THE WESTERN UNITED STATES OF AMERICA

by

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
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PREPARATION OF THIS REPORT

This report was prepared by Dr. F.J. Hester, an FAO consultant, as part of a cooperative project between FAO and the United Nations Environment Programme on Monitoring of Environmental Effects on Marine World Fishery Resources. A similar report on pollution around Japan has been prepared under the same project.

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PREFACE

In compiling this report it was necessary to rely heavily on unpublished reports and the working files of several state and federal agencies. These sources are cited by footnote. Most of the reports listed can be obtained upon request from the particular agency. Published papers are cited in the customary fashion.

Access to the working files of the U.S. Environmental Protection Agency, Regions XI and X and the cooperation of state and federal fishery agencies in Alaska, California, Hawaii, Oregon and Washington are acknowledged gratefully.

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1. SCOPE AND PURPOSE OF STUDY

1.1 Scop

This study examines direct and indirect costs of pollution as it affects the yield and marketability of marine and anadromous fishery resources of the west coast of the United States of America and associated areas in the tropical Pacific Ocean. For this purpose two types of pollution are recognized: Type I - the addition of substances to the aquatic environment that cause disruptive changes in the abundance of the biota or affect their marketability, and Type II - the physical loss or damage of aquatic habitat, or the mechanic destruction of the organisms resulting in a reduction in yield. Both conventional fisheries and aquaculture are considered.

1.2 Purpose

This study has several purposes:

- To assess the relative importance of pollution among the factors affecting the productivity of aquatic systems;
- To rank various forms of pollution according to actual and potential harmfulness;
- To provide quantitative information so that the costs of pollution control can be assessed against potential resource damage for other areas where industrialization is expanding or contemplated.

2. EFFECTS OF POLLUTION ON THE GENERAL PRODUCTIVITY OF THE AREA

2.1 Study area

The area studied comprises the five Pacific states of Alaska, Washington, Oregon, California and Hawaii; the U.S. Territories of American Samoa and Guam; and the Trust Territory of the Pacific Islands (Figure 1-1). The U.S. Canal Zone in Panama and some islands of questionable status in the Pacific have been excluded.

The considerable geographical range encompassed by the study area results in coverage of most types of habitat and types of fishery resource. The habitats include rivers, coastal bays and estuaries, continental shelf, and coastal and oceanic surface waters. The resources include pelagic fish, demersal fish and shellfish, anadromous fish, estuarine shellfish, and fish and shellfish aquaculture.

For convenience, the study area has been divided into four units:

Unit I. Alaska and the Pacific Northwest including California from the Oregon border to Pt. Conception. This unit includes temperate estuaries, major river systems, coastal shelf and coastal and oceanic waters excluding those of the California Current.

Unit II. Southern California. This unit includes only the coastal shelf and the nearshore waters.

Unit III. California Current. This unit includes the oceanic waters from about Washington south, which are part of the southward moving current system generally called the California Current.

Unit IV. Tropical Pacific. This unit includes the estuaries, lagoons and nearshore waters of Hawaii and the island territories of American Samoa, Guam and the Trust Territorie of the Pacific Islands (TT).

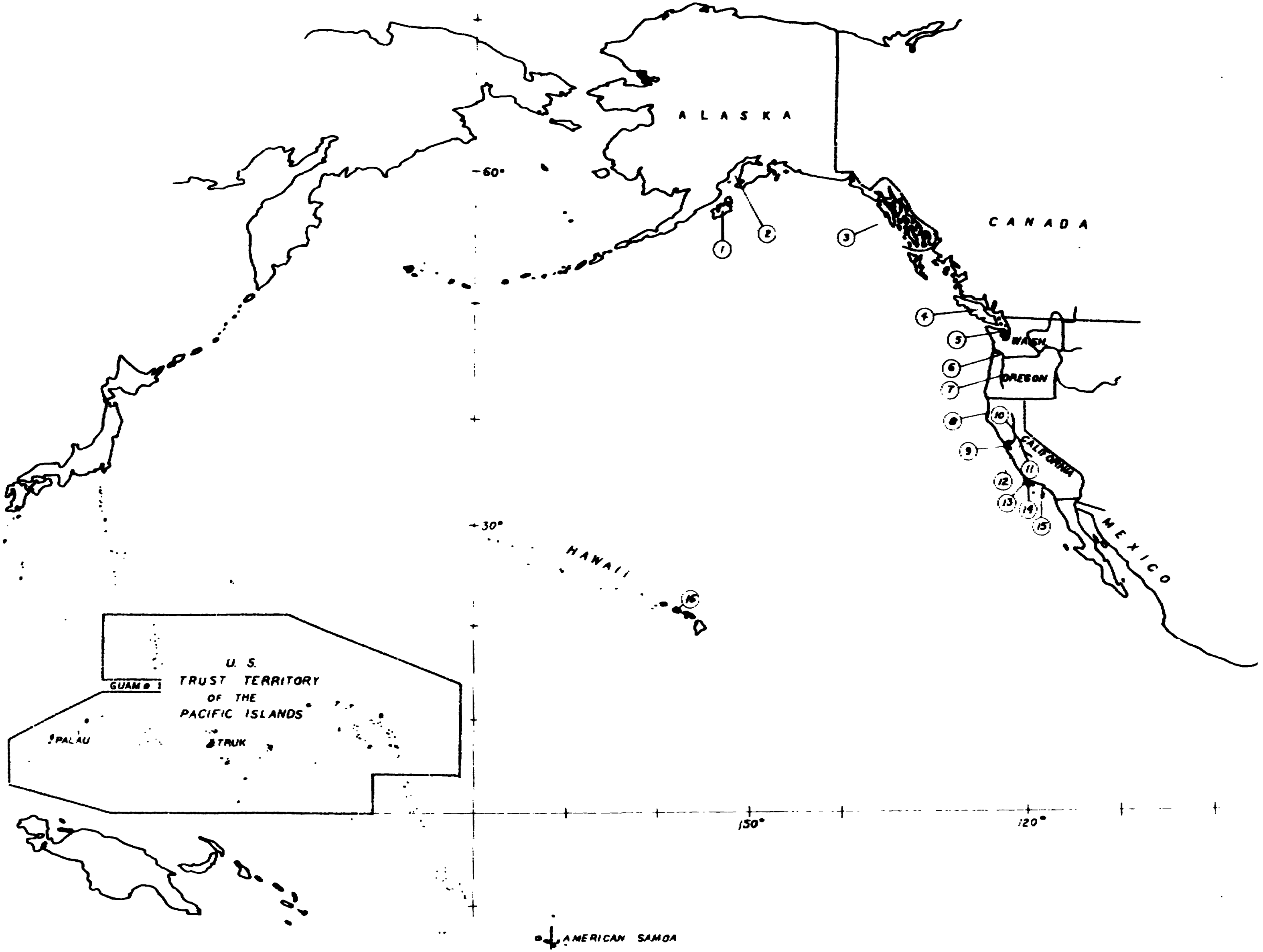

Figure 1-1 Location of places mentioned in this report: (1) Kodiak Island, (2) Cook Inlet, (3) Southeastern Alaska, (4) Vancouver Island, (5) Puget Sound, (6) Columbia River, (7) Willamette River, (8) Eureka, (9) San Francisco Bay, (10)

2.2 Substances entering these waters

Eight classes of Type I pollutants are considered in this report. These are:

(i) (Trace) heavy metals and metallic compounds

(ii) Petroleum hydrocarbons

(iii) Chlorinated organic compounds

(iv) Sewage effluent and sludge - Nutrients, Pathogens and Biochemical Oxygen Demand (BOD)

(v) Sediments

(vi) Fish processing wastes

(vii) Dumping wastes including dredging spoils

(viii) Electric power generating

Radioactive materials have not been considered in this study because of difficulties in securing data. No recent effects of these materials on the production or marketing of seafoods have been reported for the study area.

For the purpose of this report an attempt was made to provide input data based on population units. The population unit used is one million people (megacap). The assumption is that urban areas for the U.S. will in general have a common level of industrialization and living standard, which will result in grossly similar per megacap output of pollutants. This assumption will result in obviously erroneous input estimates for some types of pollutants, and in those cases more specific data are provided.

2.2.1 Sources and Loads

(i) (Trace) heavy metals and metallic compounds

Arsenic, cadmium, chromium, copper, lead, mercury and zinc, either free or as compounds, have been identified as toxic at sufficiently low levels as to be potentially hazardous to aquatic organisms, or to man through the use of the contaminated organisms. These trace heavy metals enter the marine environment from both natural and anthrogenic (related to man's activity) sources, and it is often difficult to distinguish between these origins. Most of the anthrogenic sources for the trace heavy metals are in urbanized or industrialized areas. The most complete source and loading data for inputs into the marine environment in the area is for Southern California from the Southern California Coastal Water Research Project (SCCWRP), and for Puget Sound from the Environmental Protection Agency (EPA). Estimates of total inputs from anthrogenic sources in these two areas are given in Table 2-1.

Table 2-1 Annual input into marine waters of trace heavy metals

Metal	Southern California 1/		Puget Sound 2/	
	1000s kg/yr	1000s kg/megacap	1000s kg/yr	1000s kg/megacap
Arsenic	1.5*	-	730	331.8
Cadmium	69	6.3	28	12.7
Chromium	703	63.9	376	170.9
Copper	1 399	127.2	462	210.0
Lead	1 339	121.7	847	385.0
Mercury	17	1.5	1	0.4
Zinc	4 201	381.9	340	75.7

* From vessel anti-fouling paint. Young et al. 1973.

1/ Municipal and industrial sources. From: SCCWRP 1973. TR104. The ecology of the Southern California bight: Implications for water quality management.

2/ Industrial sources only: EPA Puget Sound 305-A Report. EPA 910/-7-74-001. See also: Crecelius et al. 1975.

Comparable data are not available for other areas; however, industrialized metropolitan areas might be projected to have grossly similar inputs per magacap as the southern California unit. Areas of specialized industry might vary significantly (factor of 3 or greater) as is shown by the Puget Sound data.

All trace heavy metals are found naturally occurring in sea water. The SCCWRP studies suggest that regional inputs for some trace heavy metals may result in localized increases in natural trace metal concentrations in the waters of the California Current (Unit III). Chromium and lead are the two metal inputs considered in this report that enter the system in such great quantities that calculated levels in the sea water leaving the southern Californian bight are on the order to 20 percent higher than the sea water norm. No analytical data are provided to substantiate these calculations.

(ii) Petroleum Hydrocarbons

As with trace heavy metals, petroleum hydrocarbons (PHC) input sources are both natural and anthrogenic. The former are significant only in Unit II Southern California, and in the northern Alaska portion of Unit I Alaska and Pacific Northwest. In these areas natural oil and gas seeps contribute large quantities of PHC's to the nearshore waters. Studies in the Santa Barbara Channel (northern portion of Unit II) show that as much as 30 tons per day of natural seep oil enters these waters.1/

1/ Testimony re: Masterson v. Union, Hall v. Union. U.S. 9th Circuit Court, 1975.

Anthrogenic PHC additions to the study area are large. These are from several sources: small spills of crude oil and refined oil products; large acute spills of crude oil and refined products; discharges of oil brines from oil field production separation facilitites; oil tanker ballast water; refinery waste; and automotive associated inputs from street runoff, service stations and aerial emissions.

Some input data for these sources are available for some of the units in the study area. 1/ These data are expressed as oil and grease, however, and do not indicate the amounts of low boiling point constituents, which are not measured by the standard oil and grease method (Anon 1971). The PHC data are available only for land based sources; marine transportation input data are difficult to estimate.

Typical inputs, excluding aerial fallout, from industrialized urban areas can be expected to range from 3–8 million kg per megacap per year. These inputs would be expected to be concentrated in the areas of ocean discharge in the vicinity of the urban areas.

Marine transport inputs would be expected to be diffused along shipping lanes. In harbours and enclosed bodies of water these inputs would be diluted less quickly, and result in increased PHC concentrations in such areas. Input loads from this source, however, are low compared with population dependent inputs, and may be trivial for urbanized U.S. ports where discharge restrictions are strictly enforced.

Inputs from small spills too are trivial compared with urban discharge; however, they may be significant in areas removed from population centres, but where oil loading facilities exist.

Major acute spills (more than 500 metric tons for the purpose of this report) are rare events (Anon 1975). Major transport spills could occur anywhere in the study area but are most likely to occur near population centres where shipping is heavy. 2/ Production spills can only occur in Unit II, Southern California, and the northern part of Unit I in the Alaska area. Only one such spill has occurred on the west coast, the Santa Barbara spill of 1969 (Holmes 1969).

Table 2-2 summarizes the importance of the various sources of PHC's to the study area. The relatively high inputs from several sources for Unit II, Southern California and for San Francisco Bay in Unit I suggest that if PHC effects on fisheries can be detected, these are the places that such effects would most readily be demonstrated.

(iii) Chlorinated organic compounds

Included here are two classes of compounds: agriculture biocides such as DDT, and industrial compounds such as PCB's. The available data, chiefly from California, 3/ indicate that despite widespread use in non-urban areas, biocides enter ocean water in more concentrated amounts in the vicinity of major urban areas from municipal waste discharges and aerial fallout. Both the contributions of biocides and PCB's result primarily from manufacturing operations and cannot be extrapolated on a megacap basis to other cities where these compounds are not produced. Such discharges are decreasing

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1/ See: DPA 1974 Puget Sound 305-A Report, EPA 910/-7-74-001; SCCWRP report TR104; and Water Quality Control Plan, Vol. II. San Francisco Bay Basin. Regional Water Quality Control Board, Region 2.

2/ For example, Arizona Standard and Oregon Standard: San Francisco Bay, 1971. Spill at Anacortes, Wa. 1971. General M.C. Meigs: Washington Coast, 1972. None of these spills resulted in detectable damage to fisheries.

3/ SCCWRP, 1973 and RWQB Reg 2, 1975 op. cit.

Table 2-2 Annual average petroleum hydrocarbon (PHC) inputs into the study area: 0 = none, 1 = less than 100 tons, 2 = 100-1 000 tons, 3 = greater than 1 000 tons. Areas with potential for significant future inputs are indicated "F"

Unit and Sub-unit	Input Source				
	Metropolitan and Industrial Waste	Transport and Production	Natural Seeps	Major Spills	
				Production	Transport
UNIT I					
Cook Inlet	1	1	1	1 F	F
Prince William Sound	1	F	1	F	F
Gulf of Alaska	1	F	1	F	F
Puget Sound	2	2 F	0	0	F
Columbia River	2	2	0	0	F
San Francisco Bay	3	3	0	0	1 F
UNIT II					
Southern California	3	3	3	1 F	F
UNIT III					
California Current	1	2	2?	1 F	F
UNIT IV					
Hawaii-Oahu	2	1	0	0	F
American Samoa		1	0	0	F
Guam	1	1 F	0	0	F
TT (Palau)	1	F	0	0	F
TT (less Palau)	1		0	0	F

Note: In these confined areas, bays and estuaries, the lesser dilution of the inputs must be considered.

rapidly owing to limitations on manufacture and strict control of the manufacturing process. In 1972 inputs into the nearshore waters off San Francisco and into the bay were on the order of 3-7 metric tons of DDT and 5-10 metric tons of PCB's from all urban sources. For southern California the figures were 19-23 metric tons of DDT and 10-12 metric tons of PCB from urban sources.

The routes into the marine environment for biocides used in agriculture are varied but in general runoff and aerial fallout would seem to be the main pathways. Biocide use, particularly of the persistent compounds, has decreased markedly, but some are still permitted for some crops and in silviculture. Inputs from land runoff appear to be minor in all areas.

The San Francisco Bay area received the drainage from the California central valley agricultural areas by way of the Sacramento-San Joaquin river complex, in addition to the manufacturing input. Assuming 200 parts DDT per 10^{12} parts water[1] and an annual flow of $18 \times 10^{9} m^{-3}$ for the river system[2] suggests that an additional 3 to 4 metric tons of DDT entered the bay system from agricultural use.

Biocide use in other areas has been minor with the exception of the forests and agriculture lands of Oregon and Washington, where the chemicals would enter the Columbia River drainage system, and in Hawaii. Quantitative data from these areas are lacking.

The introduction of PCB's into the aquatic environment undoubtedly is occurring in Puget Sound, the Columbia River Basin and Hawaii, but quantitative data on these inputs are lacking. In Puget Sound high PCB concentrations were found in the sediments at the mouth of the Duwamish River. The source of this material has not been identified, but it appears likely to have been the result of a single acute incident.[3]

(iv) Sewage - sludge, nutrients, pathogens, and biochemical oxygen demand (BOD)

Sewage discharges are population dependent. The various constituents of the discharges will vary with the living habits of the population and the degree of industrialization associated with the area served by the particular discharge. In general the following ranges of major discharge constituents given in Table 2-3 apply to U.S. metropolitan areas. With some caution, these ranges can be applied to population centres in Alaska and the Pacific. In the latter case, for Oahu, Hawaii, the city of Pago Pago, American Samoa, Agana, Guam and the more densely populated areas in the TT.

[1] Based on an analysis of Sacramento River Delta water by Kaiser Engineering Co. for the State of California San Francisco Bay Delta Programs.

[2] RWQCB Reg. 2, 1975. op cit.

[3] NMFS personal communication

Table 2-3 Ranges of sewage effluent loads (1000s kg/megacap/yr) and annual loads for selected sub-units in the study area

Location	Parameter			
	BOD$_5$	Total Suspended Solids	Total Nitrogen	Total Phosphorus
Average Ranges	18 250–36 500	18 250–36 500	5 100–16 400	1 500–6 570
Unit I				
Puget Sound 1/	1 257 000 3/	2 750 000 3/	5 800	8 000
Lower Columbia River	81 000 4/	4 000 4/	1 300	600
San Francisco Bay 2/	243 000	200 000*	43 000	11 000
Unit II				
Southern California 5/	298 000	294 000	98 000	14 000
Unit IV				
Hawaii-Oahu	10 000	10 000*	5 000*	2 000*

* estimated

1/ Includes surrounding drainage (EPA 1974 op cit.)

2/ Excludes Sacramento-San Joaquin drainage (RWQCB 1975 op cit.)

3/ 85 percent contributed by pulp paper mills - total solids reported (ibid. EPA)

4/ Figure reflects mitigation control by pulp paper mills (EPA 1975. River Basin Water Quality Status report, Lower Columbia River Basin. Region X)

5/ SCCWRP op cit.

In addition to the preceding, sewage effluent can be a major source of pathogenic organisms, principally bacteria and viruses. Most discharges are into marine waters, whic result in a rapid loss of viability for most pathogens. Enclosed bays are an exception and high coliform counts and presumably unacceptable pathogen levels may occur in such areas. Areas where high coliform counts are known to occur (total coliform counts regularly exceed 1000/ml) are:

Unit I	San Francisco Bay 1/
Unit IV	Hawaii - Pearl Harbor 2/

1/ RWQCB op cit.

2/ A re-survey of the oyster resources in West Loch, Pearl Harbor. State of Hawaii, Dept. Land and Natural Resources. Div. Fish and Game, 1971

(v) Sediments

For the purpose of this report sediments include:

- total suspended solids in sewage discharges
- total settleable solids in industrial discharges
- terrigenous material from improper land use.

Source and input estimates for total suspended solids have been provided in Section 2.2.1 (iv). These data included settleable solids for Puget Sound. Settleable solid data are generally not available for most discharge data, or not differentiated from suspended solids. Sludge deposits are associated with most municipal and industrial discharges but data on their extent are generally lacking.

Settleable solids are associated with lumber and paper mills in Unit I. Quantitative data are not available for all the sub-units, but these mills have been major producers and dischargers of solids.

In addition to point source discharge, lumber and paper operations produce solid waste in log storage areas where thick bark deposits may result. In Hawaii, waste discharges from sugar mills are extensive.1/

Terrigenous sediments result from erosion caused by land development and timber harvesting. No quantitative input data are available except in some specific instances involving logging effects.2/ Qualitative source data 3/ suggest that Unit I and Hawaii in Unit IV are the areas most subject to erosional sedimentation.

(vi) Fish processing wastes

Waste discharges from seafood processing are characterized by high solids and BOD values. Cannery operations also produce considerable oil and grease. Table 2-4 lists typical discharge parameters for uncontrolled discharges from two types of processing plants.

Table 2-4 Average discharge kg per day per 1000 kg of raw material for seafood processing

	BOD_5	Total Solids	Oil and grease
Finfish cannery	22	11	3.3
Shellfish (shrimp and crab)	94	555	-

Fish processing plants are located along the coast of Units I and II; and on the island of Oahu in Hawaii, and Pago Pago in American Samoa in Unit IV.

1/ EPA Region IX, personal communication

2/ See for example Anderson and James 1957, Bishop and Stevens 1964, Brown and Krygier 1971, and Marouson 1968.

3/ EPA Region IX, X personal communication

For several reasons, input source data for fish processing plants are unavailable. The one notable exception is Kodiak Island, Alaska where a compilation of discharges for 37 processing plants has been made.1/ These data are summarized in Table 2-5.

Table 2-5 Point source discharges from seafood processors in Kodiak Basin

Type of discharge	Amount kg/day
BOD_5	43 000
Total solids	258 000
Total nitrogen	10
Total phosphorus	500

(vii) Ocean dumping

Ocean dumping is the disposal at sea of waste material too bulky or chemically active to be discharged nearshore. Substances dumped include:

- garbage and dry refuse
- chemical industrial wastes
- radioactive material
- explosives
- dredge spoils and oil drill cuttings

Dumping usually is done in designated offshore areas, and may be well removed from population centres. If the material to be dumped is highly hazardous, it is usually encapsulated and dumped at a deep-water site.

There are over 50 designated ocean dumping sites within the study area. Quantitative estimates of inputs for these sites are only partially available, and then of limited interest for this report owing to the encapsulation of much of the more interesting substances. Estimated inputs since 1945 are given in Table 2-6.

1/ EPA 1975, River Basin Water Quality status report. Kodiak Basin, Region X

Table 2-6 Cumulative dumping inputs for the study area since 1945
(1 000 000 kg)[1]

Unit and Sub-unit	Substances			
	Garbage and solid waste	Chemicals	Radioactive material	Explosives
UNIT I				
Alaska	trace	trace		
Puget Sound to Columbia River	5-10	0.1-30	trace	Amounts not available but known to be large for all units
San Francisco-Monterey	7-40	100-200	trace	
UNIT II	65	150-300		
UNIT III	trace	10-30	trace	
UNIT IV				
Hawaii	trace	5-15		

It is difficult to estimate the amounts of dredge spoils and other inert material dumped in the study area, although these quantities are considerable. One can estimate the amount of solid discharge associated with offshore petroleum production at 1 000 kg/1 of well depth. Assuming that well depths range between 500 and 5 000 m, then discharges 50-50 000 kg of cuttings and mud per well might be expected. Areas of offshore productio within the study area are in Unit I, upper Cook Inlet, and Unit II, Santa Barbara Channel

(viii) Electric power generation

Considered here are thermal pollution and mechanical damage to the biota, the latte being Type II pollution.

Thermal pollution results from the use of ocean or inland waters to cool power plan An average thermal power plant operates with a waste heat factor of 1.5-2.0. That is, it will produce 1.5 to 2.0 kw of heat energy for each 1.0 kw of electrical energy.

The amount of cooling water necessary to dissipate this heat varies with the temperature rise between the influent and effluent cooling water. Generally this rise

[1] Source: U.S. Army Corps of Engineers

[2] Source: Western Oil and Gas Association, Alaska Oil and Gas Association

is on the order of 10°C. The typical plant then requires about 2 m^3 of cooling water per kilowat per day. A 1 000 megawatt plant operating at 60 percent capacity then would use 2×10^6 m^3 of water per day.

Thermal power generation is of major significance only in Unit II where some 12 000 megawatts of coastal production occur 1/ and in Unit IV, chiefly on the island of Oahu. In Unit I much of the generating capacity is hydroelectric, but some is thermal electric, both involving chiefly inland waters. 2/

2.2.2 Habitat loss

In addition to the Type I pollution summarized in the preceding section, man has altered the environment through physical means, which may have affected the biological productivity of some fisheries. In particular, mention must be made of habitat loss through alteration of nearshore areas such as bays and estuaries, which are spawning and nursery areas for some species, and blockage of rivers and streams by dams for hydroelectric, municipal water supply and irrigation projects. Estuarine losses have been particularly great in Unit I, San Francisco Bay; Unit II and Unit IV, Hawaii. Table 2-7 summarizes these effects.

2.2.3 Effects

The effects of pollution on marine organisms have been the subject of a voluminous literature in recent years, and it is quite beyond the scope of this report to review this work. Instead, potential effects as suggested by the literature are summarized in Table 2-8. Please note that many of these effects are speculative and have not been demonstrated as occurring outside of the laboratory.

In addition to direct effects on the resource, Table 2-8 also lists direct economic effects on marketability.

2.2.4 Future outlook

Pollution abatement legislation has been enacted for the area and levels of most pollutants can be expected to decrease in the future. In addition, more stringent coastal zone use planning will slow or halt the loss of estuarine habitat.

The single most important piece of legislation affecting ocean pollution in the study area is the U.S. Federal Water Pollution Control Act of 1972. If the requirements of this act are met, by 1 July 1983 the discharge content of all pollutants into coastal and inland waters will be controlled. This implies that all point source discharges will be treated to achieve yet-to-be established acceptable standards, and non-point pollution sources will be controlled.

Since the costs of achieving the 1983 goals have been estimated as exceeding \$ 500 000 000 000, 3/ it is at present uncertain that this time schedule will be met. What does appear certain, however, is that major sources of toxic substances will be reduced, that virtually all BOD discharges will be reduced 80-90 percent, that discharged solids similarly will be reduced, and that pathogens as indicated by coliform counts will be controlled in most populated areas. Some of these reductions have been achieved since

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1/ SCCWRP *op. cit.*

2/ EPA Region X personal communication

3/ EPA, Draft National Water Quality Inventory 1975. Report to Congress.

Table 2-7 Estimated extent of aquatic habitat affected by Type II pollution

Unit and Sub-unit	Estuaries	Rivers and streams
Unit I		
Alaska[1/]	Minimal	Minimal
Puget Sound[2/]	No summary data available. Some areas obviously affected	7 out of 11 river basins have suffered some anadromous fish production loss
Columbia River[3/]	Minor development near the mouth	Since 1938 more than 2000 km of rivers and streams in the Columbia River Basin have been blocked by dams. Access to additional habitat has been restricted, but passage is provided.
San Francisco Bay[4/]	40 000 ha out of approx. 170 000 ha	
Sacramento – San Joaquin River[5/]	–	Since 1928 more than 350 km of an estimated 830 km of salmon spawning habitat has been lost
Unit II		
South California[4/]	16 000 ha of an estimated 34 000 ha	220 km (99%) of anadromous fish stream habitat has been lost
Unit IV		
Hawaii[6/]	losses chiefly filling of old Hawaiian fish ponds	

1/ Alaska Dept. Fish and Game

2/ Comprehensive Study of Water and Related Land Resources, Puget Sound and Adjacent Waters. Appendix XI 1970. Pacific Northwest River Basin Commission.

3/ Columbia River Basin Comprehensive Study 1971. Willamette Basin Comprehensive Study 1969. Pacific Northwest River Basin Commission.

4/ Coastal County Fish and Wildlife Resources and their Utilization, Calif. Dept. Fish and Game 1973 Special Report.

5/ Calif. Dept. of Fish and Game. Anadromous Fisheries Branch

6/ Hawaii Dept. of Land and Natural Resources

Table 2-8 Effects of pollutants on fishery resources

Pollutant	Effect		
	Decreased abundance	Marketability	
		Health	Consumer acceptance
Heavy metals	Acute and chronic affects reported	1/	-
Petroleum Hydrocarbons	"	2/	Tainting
Chlorinated Hydrocarbons	"	1/	-
Sewage			
(a) BOD	Acute	-	-
(b) Nutrients	May enhance for some species	-	-
(c) Pathogens	?	1/	-
Sediments	Acute and chronic by smothering. Habitat loss.	-	-
Fish processing waste	BOD main concern	-	-
Ocean dumping	Acute and chronic	1/	-
Electric power	Acute - thermal and mechanical	-	-
Habitat loss	Denial of area by physical means	-	-

1/ Sale or use of seafoods prohibited if levels in tissue exceed certain standards.

2/ No standards have been established for PHC's in seafoods. Special restrictions may be imposed on marketing seafoods from areas exposed to acute pollution.

the input loads listed earlier in this section were compiled. These include BOD, solids and oil and grease from most industrial sources, including fish processors, and the point source discharge of DDT in Unit II. Coliform bacteria counts in South San Francisco Bay have dropped from about 200 000 to about 200 MPN (most probable number)/ml between 1969 and 1972. The standards set for swimming and for shellfish production are 1 000 and 70 MPN/ml respectively.

Less likely to be affected in the near future are activities now being investigated for potential environmental harm. Included here are ocean discharges of heated effluent from electric power plants, the discharge of produced waters, that is, waters separated from the oil at the well or ashore; from offshore oil and gas development; and the dumping of dredge spoils. In addition, the need for rigorous reduction of BOD and nutrients in ocean discharges is being questioned and the proposed standards may be relaxed.

3. DIRECT EFFECTS ON FISH PRODUCTION

This section is restricted to looking for reductions in catch (or production in the case of aquaculture) that can, with reasonable probability, be attributed to pollution acting so as to change resource abundance and/or availability.

3.1 General remarks

Table 2-8 suggests that pollution has the potential for directly affecting the abundance of a resource by acute toxic effects (or mechanical destruction, e.g., entrainment in power plant intakes), or by chronic effects on the reproductive success on the resource or its food. Pollution also may affect the apparent abundance of a resource if the organism tends to avoid polluted areas or if access to fishing grounds is denied to the fishermen because of pollution.

Changes in resource abundance due to acute or chronic pollution effects on the organism or its food are extremely difficult to separate from changes in abundance from natural factors in the environment or from fishing. The data base for even the best studied fisheries in the area are insufficient to hope to be able to separate minor increases in pollution-caused mortality from natural mortality (see for example Pella and Myren 1975). Instead, effects must be detected by looking for either highly visible mass mortalities or changes in abundance that can be related to known pollution incidents, or by looking for long-term declines in abundance in areas that are known to be subject to major pollutant inputs. The former approach is quite limited in application. The latter approach is necessarily subjective, since it is difficult to show a cause-effect relation in most such cases.

The denial of access to spawning and nursery areas is easier to demonstrate, particularly when Type II pollution is involved. However, in many instances the area affected is small compared with the total area available to the organism, and the overall effect may be insignificant.

Detecting effects on availability are complicated by the tendency of commercial fishermen to avoid, either by preference or by statutory requirement, areas near major pollutant inputs such as harbors and urbanized coastal regions. The species too may avoid these areas, but such avoidance would not have an economic impact on the fishery.

For the purpose of this report it was assumed that detectable effects of pollution on fisheries most likely would be found in those areas near the known major input sources presented in section 2. Within those areas a few of the perhaps 100 species of marine organisms exploited in the study area are discussed. These species were selected because of their commercial importance or because the literature or other sources suggest that they may be particularly susceptible to pollution effects.

For convenience three habitat divisions are used for each unit: Inland and estuarine, inshore and demersal, and coastal pelagic and pelagic. These habitats and some selected major resources are considered below.

3.2 Effects on inland (anadromous) and estuarine species

3.2.1 Unit I, Alaska, Pacific Northwest and Northern California

(i) Inland

Considered here are only the five species of Pacific salmon: king *Oncorhynchus tshawytcha*, silver *O. kisutch*, pink *O. gorbuscha*, sockeye *O. nerka*, and chum *O. keta*. Commercial fisheries for these species now are permitted only in marine waters. The species are dependent upon fresh water or tidal streams for spawning. The available literature does not suggest that these species have been affected by ocean pollution, but does indicate that they have been severely affected by the pollution of spawning areas by sedimentation, by spawning area loss through dam construction and stream blockag (including BOD blockage), and by the destruction of downstream migrating young fish by passage through hydroelectric plant turbines or by diversion into irrigation systems.

King and silver salmon. Catch data show that the landings of these species have decreased markedly over the past 50 years, and that not all of this decrease can be explained by over-fishing or by natural environmental changes. No attempt will be made to estimate the historical production losses. A conservative estimate of current production losses can be made.

The data available for these species are the best for any species in the study area, but still do not always permit the separation of catch loss owing to fishery and natural environmental factors from that related to pollution.

For these species artificial propagation has halted, slowed or reversed the declines in catch. When no direct estimate of loss can be determined, the cost of artificial propagation is assumed to represent the loss.

Puget Sound[1]

Some 13 hatcheries around the Sound are involved in salmon production. The estimated annual production of king and silver salmon from these hatcheries catch (by commercial, sport and subsistence fishermen) plus escapement is 1.9 million kg and 2.3 million kg respectively. This amounts to about 50 percent of the total production (natural and artificial) for this area. The annual cost of production, not including capital costs, is estimated at $1.6 million. This cost, not the value of the fish produced, is assumed to represent a pollution loss.

Columbia River

Data are not available to indicate the fraction of salmon production provided by hatcheries, but it is large.[2] Twenty-one major hatcheries are involved. Operation and maintenance costs for these hatcheries are about $3.1 million per year.[3] This includes the production of some trout (*Salmo gairdnerii*).

[1] Pacific Northwest Basins Commission 1970 *op. cit.*

[2] Columbia River Water Management Group 1974 report

[3] NMFS

In addition to this chiefly Type II pollution "loss", high BOD levels in the Willamette River have resulted in the loss of the fall king run. This run, if it is assumed to be potentially as large as the spring run, 31 500 fish, could be expected to produce a pre-escapement catch of perhaps 90 000 fish worth commercially some $2 million (90 000 x 8.2 kg x 2.86/kg).

An estimated expenditure of some $50 million by the lower Willamette River Basin industries has been made to reduce BOD inputs in this tributary of the Columbia.1/

Northern California

Data are available from sport fishery sources 2/ that suggest that production of king and silver salmon in north coastal rivers has declined some 65 percent since 1940-50, presumably as a result of habitat loss owing to increased timber harvest in the area beginning at that time. Although no estimates are provided of losses to the commercial fisheries, conservative estimates can be made by taking only the few counting station escapement data and assuming that a multiplier of three will give the ocean catch:

Kings (three stations)	1940-50	1960-70	Difference
Average No. fish/year	25 500	9 100	16 400
Silvers (1 station)			
Average No. fish/year	14 700	5 200	9 500

Losses: King 16 400 x 3 x 8.2 kg x $2.86/kg = $1.1 million
Silver 9 500 x 3 x 3.6 kg x $2.09/kg = $ .2 million

Sacramento-San Joaquin Rivers

The same source states that king salmon runs in this river system have declined from 597 000 fish in 1953 to 332 000 fish in 1969 owing to habitat loss. Using the same assumption as for the coastal streams gives an annual loss of $18.6 million. An additional $860 000 is expended for salmon hatchery operations in California.

Other salmon (pink, sockeye, chum)

The bulk of the production of the remaining three species is in Alaska. Pollution input load data for Alaska suggest that only logging and petroleum production are important potential sources of pollution that might affect salmon production. Petroleum production to date has been confined to the Cook Inlet. Major logging operations are conducted from the Cook Inlet southward into Southeast Alaska. The Cook Inlet oil and gas development activities have not had any detectable effect on salmonid production in that area. Possible effects of logging operations have been investigated, but natural fluctuations in abundance would mask all but the most extreme effects of logging

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1/ Industry-govt. sources

2/ Citizens Advisory Committee on Salmon and Steelhead Trout

(Pella and Myren, 1975). Natural environmental factors and fishery exploitation satisfactorily explain changes in yield.[1]

In Oregon and Washington the catch data suggest that chum salmon catches have declined in coincidence with the increase in logging beginning in the 1950's. Since this species spawns in small coastal streams, it might be particularly sensitive to siltation and habitat blockage from logging operations.

Logging operations have been implicated as causing declines in salmon production along the Oregon coast (McKernan et al. 1950). Logging activities increased markedly in the Pacific Northwest in the years after 1945. Many of the operations were conducted by small-time operators who had little regard for the watershed. In recent years, stringent controls have been imposed upon logging practices. These controls and modest hatchery and habitat improvement programmes in Oregon and chiefly Washington appear to have effected a reversal of the probable logging-related decline in chum salmon landings illustrated in Table 3-1.

Table 3-1 Commercial catch of chum salmon - annual average in 1000's kg

Years	Oregon	Washington	Alaska	Total
1950-54	225	4 500	28 000	32 725
1955-59	71	1 700	24 300	26 071
1960-64	9	1 200	23 000	24 209
1965-69	2	1 500	17 400	18 902
1970-72	3	2 100	26 400	28 503

Source: Fishery Statistics of the U.S.

The total U.S. chum salmon catch during this period varied by about a factor of two. Assuming that this variation is a combination of fishery and natural factors, the Washington catch has returned to within the expected range (but was below it). The Oregon catch, however, is still well below its "expected" minimum of 112 000 kg. If this difference of some 100 000 kg is pollution-related, the annual cost at $88/kg is $88 000.

(ii) Estuaries

Estuarine pollution studies are summarized in Table 3-2. Economic losses, if any, would be minor because most areas of high pollution input have not supported major fishery production in the past. Not included here are losses because of health closures, which are discussed in Section 4.0.

[1] Alaska Department of Fish and Game. Personal communications. The Department has expressed concern over future, increased oil and gas and logging operations. Extensive investigations of possible effects and precautionary regulations are underway or contemplated.

Table 3-2 Pollutants and their effects on estuarine fisheries in Unit I

Alaska

Kodiak Harbor. Studies of shellfish waste discharges show low oxygen levels near discharges. No commercial fishing in these areas to be affected.

Source: EPA, Region X.

Southeast. Studies of log raft storage areas show extensive bottom deposits of bark. Effects variable and localized. Area affected about 260 ha, which is so minor that no detectable effects can be expected.

Source: Univ. of Washington

Washington

Puget Sound. Studies of pulp and paper mill waste showed high concentrations of sulfite waste liquor and settleable solids in Bellingham - Samish Bay, Anacortes - Guemes Channel, Everett - Port Gardner, and Port Angeles. Localized damage to marine life was reported. No estimate of effects on commercial fisheries (including shellfish aquaculture) was made. One study of reported oyster mortality at Liberty Bay involving mercury pollution gave inconclusive results.

Source: Fed. Water Poll. Control Ad., Wash. State Poll. Control Comm.

Washington

Studies of Elliot Bay - Duwamish River showed elevated levels of PCB's in the sediments. Fin erosion was evident in starry flounder Platichthys stellatus and English sole Parophrys vetulus. Elliot Bay is closed to trawling by state statute; there is no fishery to be affected.

Source: NMFS Northwest Fishery Center.

California

San Francisco Bay. Studies of the bay have been confined chiefly to pollution inputs. The fishery in the bay for bay shrimp Crago sp. is minor and erratic, and pollutional effects including habitat loss cannot be separated from changes in effort. Anadromous fish passing through the estuary do not appear to be affected since the bay supports a major sport fishery for these species. Fish surveys of Richardson Bay (northern San Francisco Bay) took 41 species represented by adults and juveniles and 7 species represented only by eggs or larvae.

Source: Calif. Dept. Fish and Game, NMFS Southwest Fishery Center.

3.2.2 Unit II, Southern California

(i) Inland

Flood control and water supply projects block the flow of all the rivers and stream in southern California. There are no anadromous fisheries in this unit.

(ii) Estuaries

Estuaries form a minor constituent of the Unit II ecosystem. About half of the original extent of these estuaries has been filled or severely modified.1/ This loss or change can be expected to have affected the abundance of organisms dependent upon estuaries for all or part of their life cycle. However, southern California estuaries are not the important production areas for commercial species as are the estuaries on the east and gulf coasts of the United States, e.g., penaeid shrimps, oysters, crabs and menhaden. Species dependent upon Unit II estuaries are, in general, protected by statute from commercial exploitation. With the exception of minor brine shrimp production in San Diego Bay and some bait fishes, no estuarine species of major commercial value occur in this unit.

At the present time there are no viable commercial aquaculture operations in Unit I There are several experimental projects. These are all associated with thermal power-generation plants.

3.2.3 Unit III, California Current

This section is not applicable.

3.2.4 Unit IV, Tropical Pacific

(i) Inland

No commercial fisheries in inland waters of this area. Anadromous species of minor importance do occur but no data on losses, if any, are available.

(ii) Estuaries

The following data, mostly qualitative, are available for the area.

1/ Source: California Coastal Zone Commission

Table 3-3 Pollution effects on commercial species in tropical estuaries

Location	Pollution Problem	Effect
Hawaii		
Pearl Harbour	Eutrophication	Highly beneficial to oyster productivity
Kaneohe Bay	Eutrophication & Sedimentation	Sedimentation has affected some reef corals. No effect on commercial fish production.*

* Note: Principal commercial fishes for which records exist are all tuna bait-fish species. Catch per unit effort for these species has increased slightly since 1960. (Source: NMFS Southwest Fishery Center) Hawaii does not have catch/effort data for other species.

Location	Pollution Problem	Effect
American Samoa	Eutrophication	None detected
TT	Some input data available but no evidence of eutrophication or effects on fisheries. The lagoon at Truk has been studied in cursory fashion for effects of ordinance component leakage from the sunken ships in the lagoon. No records are available for the commercial and subsistence fish catch from Truk lagoon, precluding the quantification of possible effects.	

3.3 Effects on inshore and demersal species

The effects of pollution on completely marine species would be expected to be harder to detect than would be effects on anadromous or estuarine species where the organisms are confined, making potential dosages greater and making the populations easier to monitor.

In marine waters dilution makes it unlikely that dosage will reach laboratory-determined acute toxicity levels - usually expressed as the 96 hour (4 day) median tolerance limit. On life stages of a commercial species that are fully recruited into a fishery acute toxicity has a high probability of detection. Such an effect would be apparent as a marked decrease in catch per unit of effort, and could be correlated with measured toxicant levels in the environment (approaching laboratory TLM values), or with a catastrophic, acute pollution incident.

The effects of acute toxicity on life stages not recruited into the fishery would be more subtle. The effect would be the same as a year-class failure from other causes. Only if environmental monitoring demonstrated high levels of pollutants could such a "year-class failure" reasonably be blamed on pollution.

For the purpose of this report it is assumed that acute pollutional effects cannot have occurred in inshore waters where major commercial or recreational fisheries exist without being detected. The search for non-catastrophic effects, however, is more difficult since non-catastrophic effects of a pollutant on an exploited species would be undistinguishable from an increase in the natural mortality rate or from year-class failures due to natural changes. In most fisheries changes in natural mortality are considered to be random over a long time period. An effect on mortality because of pollution, on the other hand, should result in an increase in the mortality rate that might be non-random and would persist until the pollutant input was removed or the species was exterminated.

Bioassaying a chronic pollution effect by looking for an increase in natural mortality in a fishery appears to be impractical since:

(1) Precise estimates of natural mortality are seldom available;

(2) Changes in the rate (in the absence of pollution) may not be random in the time-frame of the study;

(3) Selection for pollution of resistant strains may occur;

(4) The effect may act on an early life stage of the species, a stage for which estimates of natural mortality do not exist.

In the study area there have been no major investigations conducted that could be expected to detect chronic pollutional effects on even a single, well-documented fishery; although at least one, for Dungeness crab, is in progress. There have been studies made of major acute pollution incidents and one of those, the Santa Barbara oil spill, involved several fisheries. These two studies will be mentioned below. In addition, some fisheries in areas of high pollutant input will be examined in a qualitative fashion as was done with chum salmon in Section 3.2.1. This type of approach assumes that pollution may be a factor if the landings from the more polluted areas show declines that are not reflected by the stocks as a whole. Such a decline, however, cannot necessarily be attributed to pollution. Other factors, unless they can be excluded because of existing data, may be causing the observed declines. These would include overfishing, a variety of natural factors etc.

3.3.1 Unit I, Alaska, Pacific Northwest and Northern California

The inshore waters of this unit support major finfish (chiefly demersal), crab and shrimp fisheries. A finfish English sole _Paraphrys vetulus_ and the Dungeness crab _Cancer majister_ were selected for discussion. English sole was chosen because, of the more important demersal fishes, juvenile English sole enter inshore areas where they might be exposed to higher levels of pollutants. This study of the English sole is for illustrative purposes only since no pollution-related declines in finfish catch have been suggested for this unit.[1]

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[1] Pacific Marine Fisheries Commission - personal communication

Dungeness crab was selected because DDT or PCB's have been suggested as possible causative factors in the decline in abundance of one population, that off San Francisco.[1]

English sole

This species occurs, and is fished from California into southeast Alaska. Within this range the major pollution inputs occur in Puget Sound, the Columbia River and San Francisco Bay. By contrast, areas removed from these three locals may be regarded as pollution free except for some advective inputs. If one assumes that this fishery exploits only a single population, and that natural and fishing mortality are the same over the range of the fishery, then one might expect that declines in landings from Puget Sound, the mouth of the Columbia River, and/or off San Francisco Bay, that are not reflected by similar declines in landings from other areas, might be pollution related.

The problem with looking at English sole is that this species is one of several species of similar habits taken by west coast trawlers. Effort data for English sole includes the effort for other species, some of which may be more desirable depending on market conditions and may result in the selection of fishing areas less suited for English sole. Nor do these data correct for changes in gear or vessel size during this time period.

For illustrative purposes, English sole catch per unit of effort is given in Table 3-4 for five areas: two removed from major pollution inputs, and three in the vicinities mentioned above.

Table 3-4 English sole catch in metric tons per trawl hour[a]

Year	Areas remote from pollution inputs		Areas near pollution inputs			Areas combined
	Canada[b]	N. California	Puget Sound	Columbia River	San Francisco	
1966	0.030	0.047	0.036	0.067	-	0.043
1967	0.042	0.083	0.034	0.040	-	0.043
1968	0.037	0.069	0.040	0.036	0.059	0.045
1969	0.041	0.029	0.032	0.030	0.048	0.032
1970	0.067	0.023	0.024	0.029	0.036	0.027
1971	0.032	0.018	0.017	0.028	0.032	0.023

a/ Source: International North Pacific Fisheries Commission

b/ The English sole fishery in the Canadian area, north of Vancouver Island, developed during the time period. The changes in CPUE may reflect some aspects of this development.

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[1] California Department of Fish and Game

During this time period the total landings of English sole have declined from approximately 5 600 tons in 1966 to about 3 000 tons in 1971. Since catches from the areas remote from pollution inputs account for nearly half the total catch, and these areas also exhibit declines, it is unlikely that pollution is the principal factor affecting this fishery.

Dungeness crab

The fishery for Dungeness crab extends from central California to Alaska. The abundance of crabs fluctuates widely from year to year. For example the record 1969-70 season produced some 27 000 tons of crab, whereas the 1973-74 season produced less than 6 000 tons. Such changes in abundance appear to be related to changes in the ocean climate (Peterson, 1973), and tc be fishery independent.

The previous major general decline in the fishery was during the 1961-62 season. Landings to the north of the San Francisco Bay area subsequently improved. The fishery off San Francisco and the small fisheries to the south (Monterey Bay and Morro Bay areas) did not. This led to speculation that pollution (specifically chlorinated hydrocarbons) from San Francisco Bay was affecting the spawning success of crabs in the area. The California Department of Fish and Game has initiated an investigation of the problem. This investigation is just beginning and no conclusions can be drawn at this time. However there are a number of factors that suggest that pollution may not be the principal problem. These are:

(1) The fisheries south of San Francisco have followed a similar decline and recovery failure. These areas are sufficiently remote (100-250 km) from the Bay that one might expect sufficient dilution of the effluents from the Bay to have occurred. (These areas are generally downstream of the Bay in the California Current, but occasional northward near-surface flow during winter months does occur).

(2) The two to four month planktonic larval stage of the crab suggests that recruitment of crabs in the area is not dependent solely upon the local stock, but instead upon upstream stocks. Pollutional effects on eggs and early stage larvae would tend to be minimal.

(3) Most important, the area is at the southern end of the species range, and climatic variables would be expected to be most marked at the extremes of the range.

(4) The failure of the fishery may be more apparent than real. Fishing is restricted to male crabs having a carapace width over 158 mm. Because of high effort it has been assumed that fishing mortality runs from 85-90 percent on legal males in any season and that virtually all legal males are harvested within a few months of the season opening. Based on such a high fishing mortality, it also has been assumed that total catch provides a good estimate of abundance. The estimates of abundance on which the suggested pollutional decline are based come from these total catch figures. When catch per unit of effort is calculated (Table 3-5) the decline and lack of recovery is less evident, further suggesting that pollution is not a major factor in this fishery. This calculation of CPUE, however, does not consider possible changes in trip duration or in the number of crab pots pulled per trip.

Table 3-5 Dungeness crab catch and catch per trip for the San Francisco Bay area fishery[1]

Season	Catch (1000's kg)	Catch per trip (kg)
1950-51	1 724	202
1951-52	1 457	197
1952-53	1 870	237
1953-54	1 768	226
1954-55	1 926	268
1955-56	2 169	312
1956-57	4 054	473
1957-58	3 360	424
1958-59	2 279	337
1959-60	2 174	340
1960-61	1 047	197
1961-62	323	119
1962-63	650	150
1963-64	532	177
1964-65	345	153
1965-66	203	146
1966-67	180	162
1967-68	461	278
1968-69	379	226
1969-70	663	322
1970-71	298	235
1971-72	145	143

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[1] Source: California Department of Fish and Game. Catch per trip is the only measure of CPUE available from the present statistical reporting system.

3.3.2 Unit II, Southern California

Southern California because of climate, transportation, coastline, population density, high per capita income and limited inland waters, has a major amount of marine angling. As a result of sportfishing efforts, commercial fishing is subject to certain statutory restrictions that, among many, prohibit trawling for demersal fishes and purse seining for industrial fish in much of the inshore areas of this unit. Santa Monica Bay, the recipient of major pollutant inputs, is closed to most commercial fishing in the interest of sportfishing.1/

As a result of restricting commercial fishing in areas near population centres, fisheries data that might be used in this study are limited. Of the inshore commercial fisheries that do exist, all show fluctuations in catch that can be related to changes in the ocean climate or to over-exploitation. None indicate any significant declines that are pollution related. Some pollution investigations of fisheries in the area are discussed below.

Kelp

The area has a substantial kelp (the brown algae *Macrocystis pyrifera*) resource; in 1972 some 146 000 tons of kelp were harvested. The extent of these beds has declined over the past 50 years by an estimated 30 percent, but this decline has not affected the harvest. The causes for this decline are not clear. In recent years a combination of warm water in the eastern Pacific and an increase in the abundance of sea urchins has affected some major beds.2/ The decline of only one kelp bed has been related to pollution. This bed is in the vicinity of the White Point outfall off Los Angeles. The annual loss to harvest of this bed can be estimated at 100-200 tons or $2-4 000.

Demersal fishes

There have been extensive studies of the demersal fishes in the vicinity of major southern California sewer outfalls conducted by the Southern California Coastal Water Research Project. In general, these studies did not find major differences in community structure between polluted and non-polluted areas.

These studies also examined the incidence of abnormalities in demersal fishes in polluted areas. The findings showed:

(1) No greater incidence of tumours on fishes from polluted areas than have been reported for the same species from other, non-polluted areas in the Pacific;

(2) Cases of fin erosion and lesions for one species, the Dover sole *Microstomus pacificus*, appear to be related to the proximity of sewage discharge waste fields. These effects are highly localized.

(3) Structural abnormalities in some other species. These abnormalitites were not pollution related.

1/ The sport catch from Santa Monica Bay has not appeared to have suffered any pollution related decline. Source: Calif. Dept. of Fish and Game party-boat catch records.

2/ See for example the annual reports of the Kelp Habitat Improvement Project. W.M. Keck Laboratory. Calif. Inst. of Tech.

The Santa Barbara Channel oil spill of 1969 involved the release of some 5 500 tons of crude oil over a two week period. This acute pollution incident was investigated extensively for damage to the fisheries of the area. Litigation on behalf of commercial fishermen involved the fisheries for some 20 species listed in Table 3-6. Forensic ecologists found no short or long-term effects to any of these fisheries that were oil spill related (many of these fisheries were over-exploited at the time of the spill or subsequent to the spill)1/. Awards were made only for loss of access to these resources during the spill, gear damage, and vessel and gear clean-up costs.

Table 3-6 Fisheries involved in litigation following the 1969 Santa Barbara oil spill

Northern anchovy	*Engraulis mordax*
California barracuda	*Sphyraena argentea*
Pacific bonito	*Sarda chiliensis*
California halibut	*Paralichthys californicus*
Jack mackerel	*Trachurus symmetricus*
Pacific mackerel	*Scomber japonious*
Rockfish	several species of the genus *Sebastes*
White seabass	*Cynoscion nobilis*
Basking shark	*Cetorhinus maximus*
Dover sole	*Microstomus pacificus*
English sole	*Parophrys vetulus*
Petrale sole	*Eopsetta jordani*
Bluefin tuna	*Thunnus thynnus*
Rock crab	several species of *Cancer*
Spiny lobster	*Panulirus interruptus*
Abalone	several species of *Haliotis*

The effect of coastal thermal power-generating plants on marine resources in the unit is the subject of continuing investigations.2/ These studies to date have not shown that any significant effects are likely at the present level of power generation. Possible effects examined were:

(a) Destruction of fish entrained in the intake water. Preliminary studies show that minor amounts of fish are entrained in unprotected intakes of coastal generating plants. Protected intakes are now required and losses from this cause are insignificant.

(b) Destruction of eggs, larvae and juveniles entrained in the intake water. Losses from this cause are perhaps unavoidable. At present, about $8 \times 10^9 m^3$ of water annually passes through these plants. This volume is less than one percent of the upper

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1/ Masterson v. Union, Hall v. Union. U.S. 9th Circuit Court, 1975

2/ California Coastal Zone Commission and the utilities involved.

10 m of inshore waters off Southern California. Furthermore, these inshore waters are exchanged with the California current some four times per year. At this rate of flow, no effect can be expected to be detectable.

(c) Thermal effects of heated effluent on marine organisms. The area of the heated plume associated with a power plant is limited, and effects are too localized to be detectable in an open coastal situation.

3.3.3 Unit III, California Current

Not applicable

3.3.4 Unit IV, Tropical Pacific

There are no data from the area to show that pollution-related losses to inshore or demersal species have occurred. It should be noted that the fishery data for these areas are quite limited and could not be expected to detect less than catastrophic losses.

3.4 Coastal pelagic and pelagic

Studies of these fisheries for all units in the study area chiefly have been management oriented. There have been some investigations of body tissue loads of some pollutant substances: trace metals and chlorinated hydrocarbons. These studies have shown significant body burdens of some of these substances for some species. There have not been any findings to show or to suggest that the abundance of any stock has been affected.

Pollutants, chiefly DDT and its breakdown products, have been suggested as possibly affecting coastal pelagic stocks in Unit III, the California Current, specifically the Pacific sardine *Sardinops caeruleus* and the Pacific mackerel *Scomber japonicus*. However, the decline of these stocks has been explained better by a combination of overfishing and natural changes in the ocean climate (Clark and Marr, 1955; Soutar, 1967). Further, the total pelagic fish biomass for the area appears to have remained quite constant over this time period, which suggests that pollution has not affected this system.

4. EFFECTS ON MARKETING AND INDIRECT COSTS

In this section two pollution-related costs will be considered: (1) economic losses, real and potential, because of restrictions on marketing for reasons of public health; and (2) costs imposed on the industry by pollution abatement measures.

4.1 Public health

The harvesting and marketing of marine resources is subject to public health regulations. For the purpose of this report only pre-harvest contamination is considered. Such contamination is either owing to the presence of pathogens in the organism or to the presence of non-living contaminants for which rejection standards have been set.

4.1.1 Pathogens

Living contaminants that render seafoods unsafe for human consumption include parasites, bacteria and viruses. Public health standards in the U.S. specify levels of contamination based on coliform bacteria counts which, when exceeded, result in closure of shellfish beds. In the study area several such closures are in effect on a permanent basis for some potentially highly productive shellfish beds. These are:

Unit I. The 1971 National Shellfish Register lists areas of shellfish production that are closed. These areas for this unit are given in Table 4-1.

Table 4-1 Areas (ha) closed to shellfish production

	Open	Closed
Washington	71 766	16 948
Oregon	4 989	6 383
California	5 970	106 944

These waters are closed by the states because of hazardous levels of contamination. Cost estimates, if any, of these closures are not available for Washington or Oregon.

San Francisco Bay is presently quarantined. Estimates that have been made of the production potential of the bay are given in Table 4-2.

Table 4-2 Shellfish production potential for San Francisco Bay1/

Species	Potential Production (kg)	Potential Value
Oysters	6 760 000 2/	$13 000 000
Clams	1 800 000	900 000
		$13 900 000

1/ Source: Calif. Dept. Fish and Game

2/ Shucked weight

Unit II. No production areas in this unit.

Unit IV. Pearl Harbour. This area is quarantined. Surveys of the harbour in 1962 and 1971 showed a standing stock of 1.6 million kg of oysters Crassostrea virginica. Assuming harvest of 50 percent of the biomass per year the potential value is $150 000.

Elsewhere in the study area periodic closures of some shellfish areas may occur following heavy rains. The costs of such closures are minor.

Some areas in Unit IV are polluted with human waste. No data on closures, if any, of these areas are available.

4.1.2 Non-living contaminants

Public health standards have been set for a number of non-living contaminants in seafoods. To date problems with contamination of fishery products in the study area have involved only mercury and DDT. Both have resulted in marketing losses. In 1969 levels of DDT exceeding the 5.0 ppm wet weight standard were found in some loads of jack mackerel Trachurus symetricus. These loads were rejected. In 1970 and following, some loads of tuna, swordfish and other bill fish, and sablefish Anoplopoma fimbria were found to exceed the federal guidelines for mercury of 0.5 ppm and were rejected.

The DDT contamination problem appears to have been related to a single discharge source in the Los Angeles area, which has been stopped. DDT has not resulted in load rejections since 1969, but monitoring continues.

Mercury contamination throughout the study area is quite probably from natural sour and does not represent a health hazard. Despite strong evidence that this is the case, mo toring and rejection of some species continues. Monitoring and rejection costs to the can ning industry are estimated to exceed $1 million annually. Annual monitoring and rejectio costs to the fresh and frozen seafood processors are probably between $50 and $100 000. N estimate is available of rejection costs to the fishermen.

4.2 Abatement costs

Table 4-3 summarizes the costs imposed upon producers and processors in meeting air water and solid waste emission standards set by state and federal agencies. Many of these costs were difficult to obtain, and the data are approximate. They are of value mainly in indicating the magnitude of the problem. Because of the propitiary nature of some of thes figures no area breakdown is given.

5. SUMMARY OF EFFECTS AND CONCLUSIONS

5.1 Summary of effects

Table 5-1 provides a compilation of probable, documented effects of pollution on fisheries for the western United States. The figures for resources lost are obviously unde estimated since data for many areas and many actual and potential fisheries are imprecise c lacking. Excluding the potential oyster production for San Francisco Bay and type II pollu tion losses (prevention of access to critical habit or physical destruction of the organism the discernible impact on the resources in the study area is negligible compared with their more than $250 000 000 value.

5.2 Conclusions

This study suggests a number of conclusions. Though these are immediately applicabl only to the region studied here, it is believed that they are relevant to other areas, and should be of interest to those concerned with the fisheries in those areas.

(1) Poor management and natural population fluctuations have had a much greater impact on the resources than does pollution.

(2) The cost of pollution abatement is seldom justifiable solely on the basis of benefits to fisheries.

(3) BOD pollution (oxygen depletion caused by the discharge of organic wastes) is not a major factor in open waters.

(4) The potential threat to public health from Type I pollutants (substances introduced into the environment) has resulted in greater production losses than has any direct effect of these pollutants on the resource.

(5) Toxicant discharges appear to have little direct effect on resources, but the data base is unsufficient to support this conclusion beyond the time and scope of this study

(6) Type II pollution, particularly habitat loss, is more damaging than toxicants.

Table 4-3 Pollution abatement costs affecting fishing industry

Activity (major elements only)	Abatement Measures	Capital Costs			Annual Operating Costs		
		Average per unit $	No. units affected	Total $	Average per unit $	No. units	Total $
Fishing vessels	Anticipated sanitary discharge	15 000	500[1]	7 500 000	500	500	(250 000)
Processors							
Shellfish and fresh-fish	Solid wastes screening	25 000	55	1 375 000	6 500	55	358 000
	Anticipated secondary treatment	150 000	55	(8 250 000)	12 500	55	(688 000)
Tuna canners	Secondary treatment	2 000 000	9	18 000 000	150 000	9	1 350 000
Wetfish and reduction	" "	Extremely variable	5-7	500 000- 5 000 000	variable with disposal	5	50 000- 500 000
	Air emissions	150 000	5-7	750 000	40 000	5	200 000
Salmon canners	No data			Estimate 5 000 000			Estimate 500 000
Hatcheries	Anticipated costs for Columbia River		21	(7 500 000)			Not available
Totals	Present			25 625 000- 30 125 000			2 458 000- 2 908 000
	Future			(23 250 000)			(938 000)
	Potential total			49-53 000 000			3-3 500 000

[1] Ve s over 100 tons

Table 5-1 Summary of pollutants and their effects on fishery resources for the west coast of the U.S.

Unit and Sub-unit	Population (millions)	Major Type I Pollution Inputs	Major Type II Pollution Inputs	Fishery Resource	Losses ($ millions) on catch and Marketability	
					Type I	Type II
Unit I - Alaska and Pacific Northwest						
Alaska	0.2	Localized pulp mill waste, fish processing waste, oil and gas development	Logging of watershed areas	All	-[1]	-
Puget Sound	2.5	Municipal and industrial discharges of sewage, heavy metals, PHC, CHC and pulp mill wastes and dredge spoils	Logging and dams	Salmonids Shellfish and aquaculture Demersal and inshore	-	1.6
Columbia River and Oregon Coast	0.8	Municipal and industrial discharges of sewage, heavy metals, PHC, CHC, dredge spoils, and ocean dumping. Shipping	Logging and major dams	Salmonids	2.09	3.1
				Shellfish and aquaculture	-	-
				Inshore and demersal	-	-
Northern California[2]	0.2	Minor municipal, lumber mill, and fish processing wastes	Logging of watersheds	Salmonids	.65	.65
San Francisco Bay and vicinity	4.5	Municipal and industrial discharges of sewage, heavy metals, PHC, CHC, dredge spoils and ocean dumping. Shipping	Land fill. Dams and irrigation on river systems	Salmonids		19.5
				Dungeness crab	-	-
				Inshore and demersal	-	-
				Oysters and clams	13.9	-

Continued/...

Table 5- continued

Unit and Sub-unit	Population (millions)	Major Type I Pollution Inputs	Major Type II Pollution Inputs	Fishery Resource	Losses ($ millions) on catch and Marketability	
					Type I	Type II
Unit II						
Southern California	11.5	Municipal and industrial discharges of sewage, heavy metals, PHC, CHC, dredge spoils, and ocean dumping. Shipping	Land fill. Thermal power generation	Kelp	0.01	
				Inshore and demersal	-	-
Unit III						
California Current	-	Advective inputs from shore discharges, aerial fallout, dumping	-	Coastal pelagic	-	-
Unit IV - Tropical Pacific						
Hawaii	0.8	Municipal discharges, sugar mill waste. Shipping	Land fill. Thermal power generation	Inshore and estuarine	-	-
				Shellfish and aquaculture	0.2	-
American Samoa, Guam and TT	0.2	Minor, localized municipal discharges. Fish processing and shipping	Minor land fill	Inshore and estuarine	-	-
Total direct losses					A 16.85	B 24.85
Indirect costs to industry (from Table 4-3. Maximum present annual operation costs only)					A + B 41.7 2.9	
				Total annual pollution cost	$44.6	

1/ Dash denotes that effects, if any, are too minor to detect from available data

2/ Assumed loss divided between Type I and Type II pollution

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